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Research Report

# Sensory suppression during shifts of attention between surfaces in transparent motion

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ABSTRACT

During transparent motion, attention to changes in the direction of one illusory surface will impede recognition of a similar event affecting the other surface if both are close together in time. This is a form of object-based attentional blink (AB). Here, we show that this AB is related to a smaller N200 response to the change in direction and that the response is even smaller for trials on which the subject makes mistakes compared to those with correct responses consistent with signal detection theory models. The variation of N200 associated with the AB can be modeled by an attenuation of current sources estimated in visual extrastriate cortex. These results suggest that the AB in the transparent motion paradigm is due to the suppression of sensory signals in early visual areas.



## 1. Introduction

Under certain conditions, attention to one event impairs recognition of subsequent events occurring closely together in time. This capacity limitation has been well studied in experiments where different alphanumeric symbols pop up at the same location on a computer monitor at a fast pace. In rapid serial visual presentation (RSVP), target stimuli (usually words, numbers, or letters) are presented briefly, one at a time, and embedded within a stream of distracter symbols. In this case, recognition of a first target stimulus (T1) hampers identification of a subsequent target stimulus (T2) for periods lasting several hundred milliseconds, an effect known as the 'attentional blink' (AB) (Chun, 1997; Raymond et al., 1995; Shapiro et al., 1994). The AB has also been observed without the distracters when the availability of the two targets is limited by using brief presentations interrupted by visual masks (Duncan et al., 1994). In both designs, object lifetimes are usually brief.

Similar temporal constraints on attention have been demonstrated with motion stimuli in a different paradigm, rapid serial object transformations or RSOT (see Valdes-Sosa et al., 2004 for a review), which presents at once several objects for longer durations than in RSVP. This permits one to study the effect of perceptual organization on the AB. In one variant of RSOT (Valdes-Sosa et al., 2000), transparent surfaces were created by two superimposed collections of dots that rotated in opposite directions. Subjects were asked to describe the directions of two brief and consecutive changes in the flow of the dots (T1 and T2), changes that affected one surface at a time. If the two targets impinged on the same transparent surface, then both were identified accurately even when short inter-target intervals were used. However, a large impairment for

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T2 judgments was found if the two targets concerned different surfaces and if the inter-target interval was short. In other words, an AB was found only if the targets affected different objects, and thus a shift of attention was required for T2.

Another AB related to motion was described recently, but with a somewhat different procedure. Sahraie et al. (2001) presented a small circle surrounded by an annulus of moving dots. Detection of a brief color change in the circle impaired the detection of a transient episode of coherent motion affecting the moving dots if both events were close together in time. Despite a similar temporal course, it is not clear if these different ABs (found with motion stimuli) share the same mechanisms or if they are related to the classical AB elicited with alphanumeric symbols in RSVP.

Despite extensive studies of the AB with psychophysical methods (only a few of which have been reviewed above), understanding of the neural basis of this phenomenon is still very sketchy. The AB can be explained as the result of competition between the neuronal populations representing two events occurring in close temporal vicinity, as recently proposed by Keysers and Perrett (2003). Attention to T1 could bias the competition in its favor, consequently impairing the processing of T2. However, the existence of this competition, and at which level it occurs (if either perceptual or post-perceptual, and in which cortical areas), remains to be demonstrated for the different variants of AB that have been described.

Electrophysiological studies of the AB in humans are scarce and contradictory. In one study, Vogel et al. (1998) presented an RSVP stream of letter and digits. In half of their trials, a white probe was flashed together with T2 in order to explore possible modulations in the early sensory components (P1/N1) of the event-related potentials (ERPs). Despite impairment in the accuracy of T2 judgments, no suppression of the P1/N2 elicited by the probe was found during the AB. The authors concluded that the AB was not related to a suppression of sensory information and probably reflected post-perceptual processes. When infrequent (oddball) T2 were used, these elicited a late positive component (P3 or P300) that was suppressed during the AB consistent with a post-perceptual locus.

In an ERP experiment using the transparent motion paradigm reported above, Pinilla et al. (2001) report a very different outcome. During the AB, the amplitude of the N200 elicited by T2 (a change in motion direction) was reduced. This means that T2 triggered a smaller N200 in the different-surface condition relative to the same-surface condition. N200 is an ERP component provoked by motion onset or direction change that is thought to be generated in early visual extrastriate areas, with important sources in V5 (hMT/MST, see Ahlfors et al., 1999; Probst et al., 1993; Schoenfeld et al., 2002; Wang et al., 1999). N200 could thus serve as an index of the motion sensory information available for decisions. The authors of this study (Pinilla et al., 2001) concluded that the AB was associated with an attenuated sensory processing of motion signals in early visual areas.

Note that this conclusion rests on the assumption that the N200 related to the AB is partly generated in V5 (and other extrastriate areas). Previous studies (Ahlfors et al., 1999; Nakamura et al., 2003; Probst et al., 1993; Rees et al., 2000; Schoenfeld et al., 2002; Wang et al., 1999) linking N200 to MT/MST have mainly used motion-onset stimuli, instead of the changes in motion direction used in the RSOT paradigm. The generators of N200 in these two conditions may not be completely identical (Niedeggen and Wist, 1999). Moreover, any ERP component usually has several neural generators, any of which could be modified by attention (Hillyard and Anllo-Vento, 1998). Therefore, the neural sources of the attentional effect on the AB in the transparent motion paradigm have to be analyzed in more detail.

Another result adds to the uncertainty. A more recent study with the paradigm developed by Sahraie and co-workers (carried out by Niedeggen and co-workers) also found a reduced amplitude of the N200 during the AB (Niedeggen et al., 2002). In this case, the N200 was elicited by the episodes of coherent motion. However, Niedeggen and co-workers raise an important issue in their study. If N200 amplitude reflects in some way the amount of sensory information available for decision-making about motion attributes, then trial by trial fluctuations of the N200 should be related to perceptual accuracy on that trial. Therefore, if trials are sorted into those with correct responses and those with mistakes and misses, the former type of trial should be related to a larger N200. This type of effect is predicted by signal detection theory (SDT) and has been reported for several indicators of neural activity (including ERPs, fMRI and single unit studies) (Britten et al., 1996; Corbetta et al., 2000; Hawkins et al., 1990; Ress and Heeger, 2003; Shulman et al., 1999) in response to visual stimuli.

Intriguingly, in their study, Niedeggen and co-workers found no difference in N200 amplitude for the types of trial analyzed: trials with correct and missed responses. However, these two types of trials did have different P300 amplitudes. The authors concluded that, despite the fact that the AB was associated with a lower N200 amplitude, this effect did not index sensory suppression that could contribute to the AB. Additionally, they argue that, since Pinilla et al. (2001) did not compare ERPs from trials related to correct and incorrect responses, there is insufficient evidence to relate reduced sensory processing with the AB in their paradigm.

To summarize, two issues are informative about the possible role of sensory suppression during the AB related to transparent motion. Firstly, more direct evidence must be obtained that the N200 effect described by Pinilla et al. (2001) derives from the modulation of generators in extrastriate cortex (i.e. V5). This issue may be addressed by recording ERPs with a high density of scalp electrodes and modeling the intracranial sources of the attentional effect (i.e. the difference waveform obtained by subtracting ERPs affected by the AB from ERPs not affected by the AB). Secondly, a more direct tie must be established between perceptual accuracy and N200 amplitude. This means averaging separately the ERPs from trials with correct responses from those with incorrect responses and applying concepts derived from SDT. These issues were examined in the present study.